UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NPRDC TR 87-11	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Navy Personnel Research and Development Center 6b. OFFICE SYMBOL (If applicable) Code 61	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) San Diego, CA 92152-6800	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Navy Military Personnel Command 8b. OFFICE SYMBOL (If applicable) NMPC-40	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20370-5000	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
63707N	Z1770	MP006	

11. TITLE (Include Security Classification)
ENLISTED PERSONNEL ALLOCATION AND NOMINATION SYSTEM (EPANS): PROTOTYPE FOR THE ADMINISTRATIVE/DECK/SUPPLY RATINGS

12. PERSONAL AUTHOR(S)
Liang, Timothy T., Thompson, Theodore J., and Zimmerman, Geoffrey L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 84 Oct TO 86 Jun	1986 December	47

16. SUPPLEMENTARY NOTATION
See also NPRDC TRs 84-41, 84-49, and 86-24.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Multiple criterion optimization, network flow model, personnel assignment, personnel allocation
12	02		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

An assignment optimization model was developed for selected ratings from the Admin/Deck/Supply Assignment Branch at the Naval Military Personnel Command. A large-scale capacitated network model is used to integrate assignment policies, allocation policies, and person/job eligibility criteria. This model provides an automated aid for detailers and allows consideration of all possible assignments to find the best set of matches for a given group of personnel and jobs.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Liang, Timothy T.	22b. TELEPHONE (Include Area Code) (619) 225-2371 22c. OFFICE SYMBOL Code 61

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Navy Personnel Research and Development Center
San Diego, CA 92152-6800 NPRDC-TR-87-11 December 1986

THE ENLISTED PERSONNEL ALLOCATION AND NOMINATION SYSTEM (EPANS):

PROTOTYPE FOR THE ADMINISTRATIVE/DECK/SUPPLY RATINGS

NPRDC TR 87-11

December 1986

THE ENLISTED PERSONNEL ALLOCATION AND NOMINATION SYSTEM (EPANS): PROTOTYPE FOR THE ADMINISTRATIVE/DECK/SUPPLY RATINGS

Timothy T. Liang
Theodore J. Thompson
Geoffrey L. Zimmerman

Reviewed by
Joe Silverman

Approved by
Martin F. Wiskoff

Released by
B. E. Bacon
Captain, U.S. Navy
Commanding Officer

Approved for public release;
distribution is unlimited.

Navy Personnel Research and Development Center
San Diego, California 92152-6800

FOREWORD

This report was prepared as part of work unit R1770-MP006 (Enlisted Personnel Assignment Systems). The objective of this project is to develop computer-based models to improve the Navy's personnel assignment system.

The central feature of the Enlisted Personnel Allocation and Nomination System (EPANS) is an automated assignment model. It was developed to assist detailers at the Enlisted Personnel Management Center (EPMAC) in assigning nonrated personnel. The Naval Military Personnel Command (NMPC) has requested that the EPANS approach be expanded to cover rated personnel. A modified version was therefore developed to nominate assignments for selected ratings in the Administrative/Deck/Supply Assignment Branch at NMPC. Test and evaluation of the prototype will begin in early 1987 for the Quartermaster rating, followed by trials for additional ratings. During trial implementation, EPANS will run parallel to the current manual systems and be refined and modified to meet NMPC's needs. EPANS does not yet handle assignments that require extensive enroute training, but current plans anticipate the development of similar models for ratings with extensive training requirements.

This report is the fourth in a series. Previous reports describe an approach for developing aggregate numerical allocation goals (NPRDC TR 84-41), a network formulation to solve the Navy's personnel assignment problem (NPRDC TR 84-49), and the development of an automated assignment model for Seaman, Fireman, and Airman apprentices (NPRDC TR 86-24).

We appreciate the support of CAPT B. A. Spofford (NMPC 40), CDR D. M. Chown (NMPC 40B), CDR R. Moore (NMPC 405) and LCDR A. Karnas (NMPC 470) in providing advice and information on the enlisted assignment process.

B. E. BACON
Captain, U.S. Navy
Commanding Officer

JAMES W. TWEEDDALE
Technical Director

SUMMARY

Background and Problem

Enlisted personnel assignment in the Navy is a very complex and difficult task. Numerous eligibility rules must be followed and many conflicting assignment policies must be considered. Also, there is a large volume of assignments. Because of these factors, it is humanly impossible for detailers to calculate all possible combinations of person/job matches, let alone find the optimal set of assignments from a policy standpoint. Detailers and managers need methods that will reduce their workload, help them make accurate and efficient assignments, and execute multiple assignment policies effectively. The Enlisted Personnel Allocation and Nomination System (EPANS), a computer model, provides help by quickly creating lists of potential assignments that satisfy eligibility and policy criteria. EPANS development so far, however, has been limited to nonrated personnel.

Objective

The objective of this research was to expand the EPANS method to handle the assignment of Administrative/Deck/Supply (A/D/S) ratings at the Naval Military Personnel Command (NMPC).

Approach

A large-scale capacitated network model was used to integrate eight assignment policies and numerous eligibility criteria. This report describes the version of EPANS for ratings in the A/D/S Assignment Branch at NMPC, which do not require extensive enroute training. Specifically, this includes the QM, SM, BM, SH, PN, MA, AK, DK, MS, SK, and YN ratings for all nine paygrades. The method can be adapted for the remaining ratings handled by the A/D/S branch at NMPC.

Results and Discussion

The version of EPANS for the A/D/S Branch at NMPC simultaneously considers all people and jobs to obtain the optimum assignment configuration. The model frees the detailers' time so that they can carefully review the assignment nominations and special cases that arise. Eligibility criteria and assignment policy priorities are under the direct control of the manager, and alternative ways of executing policies can be costed out before actually making assignments.

Plans

The EPANS prototype for the QM rating will be tested early in 1987, followed by trial implementation for additional ratings. During test and evaluation, EPANS will run parallel to the current manual system. The model will then be modified and refined to meet NMPC's needs. Future work on EPANS involves the development of an expanded version of the model for assignments that require extensive enroute training.

CONTENTS

Page

INTRODUCTION 1

ASSIGNMENT MODEL DEVELOPMENT 2

- The Assignment Problem 2
- Development Strategy 4
- Data Structure 4
- Eligibility Criteria 4
- Assignment Policies 7
- Allocation Policies 8
- Model Formulation 8
- Relative Importance of Policies 8

COMPUTATIONAL FEATURES 9

POLICY ANALYSIS 10

- Rearranging Policy Priorities 10
- Changing Eligibility Requirements 14

CURRENT STATUS AND DEVELOPMENT PLANS 17

REFERENCES 19

APPENDIX A--EXAMPLE ASSIGNMENT PROBLEM A-0

APPENDIX B--NETWORK FLOW MODEL FOR ASSIGNMENT OF RATED PERSONNEL B-0

APPENDIX C--QUANTIFICATION OF ASSIGNMENT POLICIES C-0

APPENDIX D--THE EFFECTS OF SCALING ON POLICY TRADEOFFS D-0

DISTRIBUTION LIST

LIST OF TABLES

Page

1. Number of Possible Combinations Associated With Various Assignment Situations 3

2. Personnel and Job Information Considered in the Assignment Decision 5

3. Prescribed Tour Lengths 6

4. Male-Only Ship Types 7

5. EPANS Computational Results on an IBM 4341 Model 12 9

6. Policy Tradeoff: PCS Cost Versus Location Preference (LOCPREF) 10

7. Policy Tradeoff: PCS Cost Versus Requisition Priority (REQPRI) 12

8. Policy Tradeoff: Requisition Priority (REQPRI) Versus Location Preference (LOCPREF) 13

9. Policy Satisfaction Impact of Changing Eligibility Rules: Introducing Paygrade Substitution (PGSUB) 15

10. Policy Impact of Changing Eligibility Rules: Increasing Allowable Time Lag 17

A-1. Listing of All Assignment Combinations for Example Assignment Problem A-3

A-2. Location Preferences and Job Locations A-5

A-3. Summary of Results for Example Assignment Problem A-7

LIST OF FIGURES

1. The Enlisted Personnel Allocation and Nomination System (EPANS) 1

2. Paygrade substitution scenario 14

B-1. Network flow model for rated assignment B-2

INTRODUCTION

The Navy has numerous rules, regulations, and policies that govern the assignment of its 500,000 enlisted personnel. Assignment decision makers (detailers) attempt to satisfy individuals' location preferences, control permanent change of station (PCS) costs, and satisfy several other assignment policies. As they perform these functions, they must satisfy a complex set of eligibility rules and stay within aggregate resource allocation plans. In addition, the requirements of sea/shore rotation create a large volume of assignments every month. Therefore, detailers make a large number of assignments, each of which must satisfy complex eligibility requirements while simultaneously considering many policies.

In the interest of reducing detailers' workloads and improving policy execution, the Navy has devoted resources to automating personnel and job information. Although these efforts have produced various data retrieval systems that make assignment information more accessible, actual assignments are still performed manually. Due to the large volume of assignments, it is humanly impossible for detailers to consider all possible person/job matches to find the optimal solution from a policy standpoint.

The Enlisted Personnel Allocation and Nomination System (EPANS) was developed by the Navy Personnel Research and Development Center (NAVPERSRANDCEN) to fill this need for rapid matching of people to jobs based on multiple policy criteria. Descriptions of EPANS are contained in Blanco, Liang, Habel, and Ritter (1984); Liang (1984); Liang and Lee (1985); and Liang and Thompson (1986, in press).

EPANS is a large-scale capacitated network model that uses information on available personnel (avails), requests to fill job vacancies (requisitions), and personnel distribution objectives among the fleets (see Figure 1). It generates an optimal set of person/job nominations within a given priority sequence of policies. The model is structured so that detailers and managers have complete control over the policy sequence and eligibility criteria. The detailer may then accept or override any or all of EPANS' nominations in making the final assignments.

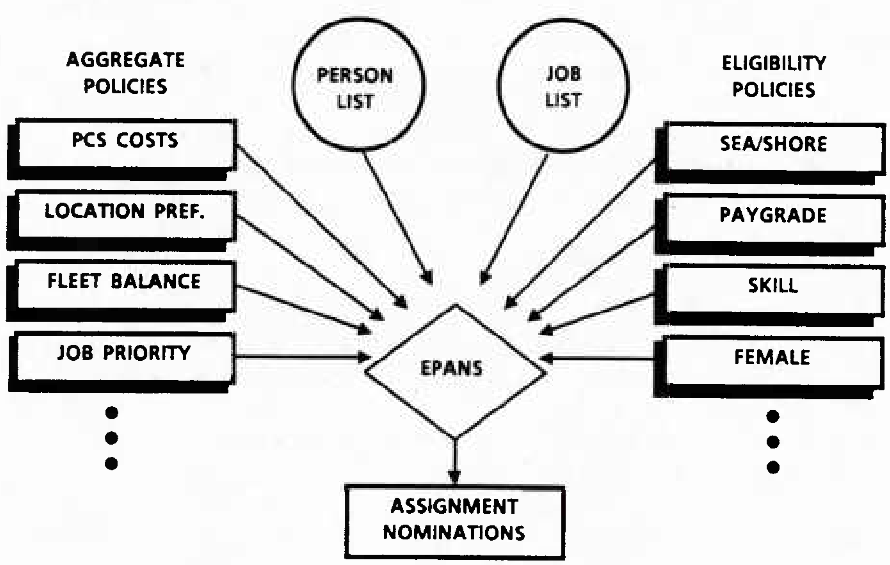

Figure 1. The Enlisted Personnel Allocation and Nomination System (EPANS).

EPANS is currently awaiting implementation at the Enlisted Personnel Management Center (EPMAC), New Orleans, for the assignment of Seaman (SN), Fireman (FN), and Airman (AN) apprentices.[1] The consensus of the detailers at EPMAC is that EPANS makes accurate assignments and executes policy effectively. A typical week's workload at EPMAC is 600 avails and 2,000 requisitions. For a problem of this size, EPANS requires only about 44 minutes of central processing unit (CPU) time and less than 2 megabytes internal storage on EPMAC's mainframe computer (IBM 4341). By starting from a base of mathematically optimal person/job matches, EPMAC detailers will have more time to handle special cases.

EPANS needs to be modified and expanded to handle rated personnel. Building a single model to accomplish this objective is difficult, because assignment procedures are very complex and cannot easily be standardized to cover all ratings and skill levels. Therefore, a separate version of EPANS needs to be developed for specific ratings or groups of similar ratings/communities.

The objective of the research reported here was to develop a version of EPANS for the ratings in the Administrative/Deck/Supply (A/D/S) Assignment Branch at the Naval Military Personnel Command (NMPC). These ratings require little or no enroute "C" school training.

ASSIGNMENT MODEL DEVELOPMENT

The Assignment Problem

Given a group of avails, a list of current requisitions, a set of eligibility requirements, and a number of policy objectives, the detailer makes a set of assignments. Ideally, once a priority sequence of assignment policies is determined, all possible sets of assignments can be identified so that the best set of assignments can be selected. Unfortunately, this procedure involves a very large number of choices. In fact, for the typical number of people and jobs faced by the detailer, it is humanly impossible to calculate the policy implications of every possible combination of person/job matches. The total number of possible assignment combinations is typically very large.[2]

Suppose we only consider situations where the number of people and the number of jobs are equal. If there are no eligibility restrictions, the maximum possible number of different assignment combinations for various-sized problems is shown in Table 1. Given the fact that assignment activity during a typical requisition cycle may involve 100 or more people and jobs, manually identifying all possible combinations of assignments and then finding an optimal combination is clearly a human impossibility.

---

[1]Implementation at EPMAC is awaiting the development of the Enlisted Assignment Information System (EAIS), the source of operational data needed by EPANS.

[2]For an assignment problem with m people and n jobs, the total number of possible assignment combinations, T, is given by the following formula:

$$T = m!/(m-n)! \quad \text{for } m > n$$

or

$$T = n!/(n-m)! \quad \text{for } n > m$$

The figures shown in Table 1 represent the upper boundary on the size of a given assignment problem for a specific number of persons and jobs. It was assumed that each person is eligible for every job. However, this is typically not the case. If eligibility is taken into account, the figures in Table 1 can be reduced quite a bit. But, even when we do this, typical assignment problems are still too large to manually calculate the policy implications or every possible assignment combination.

Table 1

Number of Possible Combinations Associated With Various Assignment Situations

No. of People	No. of Jobs	No. of Different Combinations
2	2	2
3	3	6
4	4	24
5	5	120
6	6	720
7	7	5,040
8	8	40,320
9	9	362,880
10	10	3,628,800
11	11	39,916,800
12	12	479,001,600
13	13	6,227,020,800
.	.	.
.	.	.
.	.	.
50	50	3.04×10^{64}
.	.	.
.	.	.
.	.	.

To illustrate this point, we provide an example assignment problem in Appendix A. In the example, we have five avails and seven requisitions to choose from, with each avail being eligible for only a few jobs. Even with an assignment problem this small, we find that there are 456 different ways to assign all five avails, as shown in Table A-1 (see Appendix A). First, we compare manual and automated assignment, assuming that minimizing PCS cost is the only assignment policy. Then we introduce a second assignment policy, satisfying location preference, and recalculate solutions using both manual and automated procedures. In both cases, the only procedure available to the unaided detailer (the sequential matching of manual assignment) was unable to find the optimal solution for these five people, whereas matching using network optimization techniques (a computer model) always achieves the optimal solution.

Development Strategy

As mentioned previously, EPANS was developed for the assignment of SN, FN, and AN apprentices. When we began expanding EPANS to cover rated personnel, it was convenient to begin with ratings that do not require extensive training. We chose to start with the A/D/S branch at NMPC because it assigns a large number of personnel who require little "C" school training. Specifically, this report documents the development of a version of EPANS for the assignment of QM, SM, BM, SH, PN, MA, AK, DK, MS, SK, and YN avails. The new version of EPANS will cover all nine paygrades, unlike EPMAC's version, which covers nonrated (E-1 through E-3) personnel only.

Data Structure

Rated personnel who become available for assignment can be divided into three groups. First, individuals attending "A" school appear on the detailer's list of avails as they near their graduation dates. Second, rated personnel who are nearing completion of a tour of duty become available for assignment on their projected rotation date (PRD) and are called PRD rollers. The third group of avails becomes available for assignment for various other reasons. Certain members may be released from a hospital or temporary duty while others may drop out of school. Most of the avails fall under the first two categories. The version of EPANS described in this report models only the assignment of "A" school graduates and PRD rollers.

Table 2 lists personnel and job information that EPANS uses to make assignment nominations. These data are used for determining person/job eligibility and the "costs" of assigning a given person to a given job. The cost data for individuals allow the computer to identify, through manipulation of alternative assignments for many individuals, an optimal set of assignments that satisfies a variety of policies.

The personnel distributions among the fleets (Fleet Summary Data) are also needed to develop aggregate numerical allocation goals. These data include billets and personnel by groups called composites. Composites are defined by paygrade group, Chief of Naval Operations (CNO) priority, duty type (sea/shore), and Manning Control Authority (MCA).[3]

Eligibility Criteria

Detailers must follow a complex set of rules and regulations when assigning rated personnel. These rules take the form of restrictions on what kind of personnel characteristics are allowed when filling a particular type of billet. For instance, only U.S. citizens may fill overseas shore duty jobs. The eligibility criteria for the assignment of rated personnel can be grouped into several categories.

Type of duty. Male "A" school graduates are eligible only for sea duty. Female "A" school graduates are eligible for sea duty or overseas shore duty. The eligibility of PRD rollers for new assignments depends on their current duty, paygrade, and tour length. For instance, if a member is currently at sea duty and his PRD coincides with or is near the end of his tour of duty, he would be eligible for shore duty. If the individual is far from completing his tour, he can be assigned to sea duty. The prescribed tour lengths in effect at this time for each rating are reported in Table 3.

[3] The three MCAs are Commander in Chief, U.S. Pacific Fleet, Commander in Chief, U.S. Atlantic Fleet, and Commander, Naval Military Personnel Command.

Table 2

Personnel and Job Information Considered in the Assignment Decision

Personnel Information	Job Information
1. Name	1. Rating requirement
2. Social Security number	2. Paygrade requirement
3. Rating	3. NEC requirement
4. Paygrade	4. Location
5. Date of availability	5. Job vacancy date
6. Class of availability	6. Requisition priority
7. Current assignment	7. Chief of Naval Operations priority
8. Current location	8. Sex restrictions
9. Location preference	9. Sea/shore code
10. Sex	10. Manning control authority
11. Number of dependents	11. Special qualifiers
12. U.S. citizenship	12. Nuclear powered ship
13. Security clearance	13. Reserve ship
14. Overseas qualifications	14. Ship type
15. End of active obligated service	15. Female allowed ship
16. Projected rotation date	
17. Sea duty commencement date	
18. Shore duty commencement date	
19. NECs earned	
20. Performance scores	
21. Tour length	

Table 3

Prescribed Tour Lengths (in Months)

Paygrade	PN	SH	SM	QM	BM	MA	AK	DK	MS	SK	YN
						Rating					
						Sea Duty					
E-1--E-3	39	60	60	60	60	39	36	36	42	39	39
E-4	39	60	60	60	60	39	36	36	42	39	39
E-5	36	48	60	60	60	39	45	42	42	39	39
E-6	36	48	54	60	54	39	36	48	42	45	36
E-7	36	36	45	57	51	39	39	36	36	42	36
E-8	36	36	36	42	51	39	39	36	36	36	36
E-9	36	36	36	36	51	39	42	36	36	36	36
						Shore Duty					
E-1--E-3	45	24	24	24	24	36	24	24	24	27	45
E-4	45	24	24	24	24	36	27	24	24	27	45
E-5	45	24	27	24	24	36	30	24	24	27	45
E-6	48	30	27	24	30	36	36	24	24	24	45
E-7	48	36	24	27	24	36	57	54	30	24	45
E-8	57	54	36	30	24	36	48	54	30	24	45
E-9	57	54	36	36	24	36	36	60	36	36	45

Overseas restrictions. Certain individuals are not eligible for overseas duty. Males who have just completed an overseas tour may not be assigned to overseas duty. Avails with four or more dependents are not eligible for overseas jobs. For certain members, a special "comment" restricting eligibility for overseas jobs might be specified. For example, "A" school graduates with NMPC-directed availability (class of avail = "DX") may not be assigned to overseas duty.

Special job qualifiers. Certain requisitions will display a 3-digit auto remark code that is a special job qualifier placing additional restrictions on assignment. There are over 700 of these codes. These 700 codes are grouped into six special job qualifiers. The six categories are as follows:

1. Person must be overseas qualified.
2. Limited duty avails not eligible.
3. U.S. citizenship required.
4. Person must not report for duty earlier than the job vacancy date.
5. Male-only billet.
6. Temporary change in activity location for overhaul.

NEC restrictions. If the requisition has a Navy Enlisted Classification (NEC) requirement, an avail is eligible if the NEC has already been earned, or if the avail is qualified for the appropriate training. The individual is considered qualified for training if his performance score is 3.8 to 4.0 and the trend for the last three periods averages more than 8 out of a possible 9. Everyone is eligible for jobs that require an NEC earned through on-the-job training. Certain NECs (e.g., dog handlers) are skipped for manual assignment.

Other criteria. Limited duty personnel are not qualified for sea duty or overseas duty. Females are not allowed on male-only (i.e., combatant) ships. A complete listing of male-only ship types is given in Table 4. Some "A" school graduates have coast guarantees that limit the number of billets for which they are eligible. Finally, certain avails are skipped entirely. For instance, individuals with certain NECs are not handled by EPANS. Members participating in special programs, such as the Spouse Program, are also skipped.

Table 4

Male-Only Ship Types

AE	AVM	LPH
AFDB	AVT	LSD
AFDL	BB	LST
AFDM	CG	MCM
AFS	CGN	MSO
AGDS	CV	NR
AGF	CVN	PCH
AGSS	DD	PHM
AO	DDG	SSAG
AOE	FF	SSBN
AOR	FFG	SSN
ARD	LCC	YTB
ARDM	LHA	VA
ATF	LKA	ASR
ATS	LPD	VAW

Assignment Policies

The Navy has a variety of policies governing the assignment of rated personnel. These policies may be in conflict with one another. Therefore, it is necessary to determine a priority sequence of policies before executing EPANS. Also, it may be desirable to exclude certain policies from time to time. EPANS can optimize assignments according to any subset or all of the eight policies listed below, in any order specified by NMPC.

1. Satisfy individual location preference.
2. Assign personnel with NECs to jobs that require that NEC.
3. Minimize moving distance.
4. Fill requisitions in priority order.
5. Females scheduled for sea duty may go to overseas shore duty if there are no sea jobs.
6. Match person's paygrade to job paygrade.

7. Fill CNO priority jobs first.
8. Minimize difference between personnel availability date and job vacancy date.

Allocation Policies

Allocation policies are designed to influence the assignment process to achieve certain aggregate goals. These goals are measured by manning, which is defined as the percent of billets authorized that are filled by personnel.

There are three allocation policies. One policy is to fill all Chief of Naval Operations (CNO) priority jobs. Another policy is allocation by duty type. Sea duty jobs are filled first, followed by shore duty. Yet another policy is allocation by Manning Control Authority (MCA). The goal of this policy is to balance manning across MCAs.

Each allocation policy is defined separately for three paygrade groups: (a) E-1 through E-4, (b) E-5 through E-6, and (c) E-7 through E-9. The model allows both allocation and assignment policies to be specified in any order.

Model Formulation

When the detailer enters specific eligibility requirements or policy priorities into EPANS, the computer generates a matrix for making assignment nominations. This is called model specification or model formulation. The network flow model then integrates eligibility, assignment policies, and allocation policies into a single model that takes personnel, job, and Fleet manning information into account and generates a series of person/job matches. These matches are the nominations for assignment. The detailer may accept all, some, or none of the nominations as final assignments. The fact that all people and assignment decision criteria are incorporated in a single calculation procedure allows us to consider all feasible person/job combinations for a group of avails and optimize all assignment and allocation policies simultaneously. A complete description of the network formulation of the model is in Appendix B. An explanation of how the assignment policies are quantified is given in Appendix C.

Relative Importance of Policies

EPANS ranks the relative importance of assignment criteria and policies as follows:

1. Satisfying eligibility criteria.
2. Maximizing the number of assignments.
3. Optimizing allocation and assignment policies (order specified by the user).

Person/job eligibility criteria are always the most important. If a person is not eligible for a job, EPANS will never nominate the person for that job. The next most important policy is maximizing the number of assignments. Maximum assignment of personnel is an implicit goal of the EPANS model. In other words, all people that can be assigned will be assigned, but the matching of people to jobs is done in a way that minimizes the total cost of flow through the network. Third most important are the allocation policies and assignment policies previously described. These two types of policies are listed together because EPANS allows these policies (or any subset thereof) to be considered in any order specified by NMPC.

It should be noted that some kinds of policies can be alternatively treated as eligibility rules, allocation criteria, or assignment policies. For example, CNO priorities are handled by an allocation policy that specifies that CNO priority jobs must be filled until the manning in these billets is at least 100 percent. Alternatively, these billets could also be filled using an assignment policy that specifies that all CNO priority jobs must be filled before any non-CNO priority jobs are filled. Another example would be when for some specific reason, a particular person/job match for one individual should not be made. This option can be accomplished through EPANS with the use of eligibility criteria by simply making the person ineligible for the job. Alternatively, the match could be made highly unlikely by attaching a very high cost to it.

COMPUTATIONAL FEATURES

EPANS consists of a series of FORTRAN programs that perform the following procedures: (a) pre-processing of personnel and jobs for assignment optimization, (b) model formulation, (c) assignment optimization, and (d) report generation. A modified version of GNET (Bradley, Brown, & Graves, 1977) is used in the assignment optimization module.

As an example of the computing time required by EPANS, Table 5 shows the computational results of matching people to jobs for six of the ratings covered in this report. These particular runs were for all paygrades of rotating personnel in each rating. For instance, the entire model required about 3 minutes of CPU time on an IBM 4341/12 computer to match 192 BM personnel to 835 requisitions. On average, 23 percent of the CPU time was used for model formulation, 65 percent of CPU time was used for model solution, and 12 percent of CPU time was used for report generation.

Table 5

EPANS Computational Results on an IBM 4341 Model 12

Item	Rating					
	QM	SM	BM	SH	PN	MA
Number of people	83	76	192	164	94	58
Number of jobs	359	276	835	719	575	288
Number of nodes	444	354	1,029	885	671	348
Number of arcs	1,619	1,040	10,660	4,838	1,760	852
Number of policies	8	8	8	8	8	8
Total time in CPU seconds	24	16	163	76	31	13
Model formulation	10	7	37	21	10	6
Network optimization	9	5	107	44	15	4
Report generation	5	4	19	11	6	3

Note. Networks with up to 1,500 nodes and 50,000 arcs can be solved using less than two megabytes of core storage.

The number of people and jobs in Table 5 represents a 1-2 week workload for each detailing community. Among other things, the savings in time makes it possible to make a variety of EPANS runs with different orders of assignment policies, and to estimate the cost of alternative ways of doing business. Personnel who do not get nominated by the model can still be assigned manually, but the time savings offered by EPANS allows the detailer to devote special attention to these individual cases.

Another advantage of EPANS is its ability to simultaneously consider all assignment policies while searching for the optimum set of assignments. Since all optimization routines implicitly try to maximize the number of assignments within eligibility limitations, the final solution may contain a nomination that may seem at odds with a particular assignment policy. For instance, suppose minimizing PCS cost has top priority among all assignment policies. Further suppose that the solution generated by EPANS contains a nomination involving a long distance move. In isolation, this assignment may seem costly. However, the overall PCS cost of the entire set of assignments for that particular run has been minimized.

To gain further insight into the implications of manipulating the various parameters that control EPANS, we now examine policy tradeoffs.

POLICY ANALYSIS

We will examine two different ways in which assignment policies can be affected by using EPANS: (a) changing the priority sequence of assignment policies and (b) changing eligibility requirements. We first examine the effect of changing the policy order.

Rearranging Policy Priorities

To simplify matters, suppose there are only two important assignment policies: (a) minimizing moving cost (PCS) and (b) satisfying the individual's location preference (LOCPREF). Tradeoffs between these policies inevitably occur during the search for the optimal set of assignments. For example, an individual may have to settle for an unwanted location if the distance to a desired duty station is too great. In EPANS, the proxy for PCS cost is moving distance.

In order to gain insight into the tradeoffs that are possible between these two policies, the same data used to produce the results in Table 5 were used to run EPANS with different policy sequences. Specifically, EPANS was run twice for each of the six ratings. First, a set of assignments was made with LOCPREF as the top policy followed by PCS. Then, the same data were rerun with PCS taking precedence over LOCPREF. The results of these runs are reported in Table 6.

Table 6 shows that in order to meet more location preferences, the Navy must spend more PCS dollars. This relationship is well-known, but the figures reported here quantify the magnitude of the tradeoff and show the wide differences among ratings. For instance, 83 QM personnel and 359 QM requisitions were input to EPANS for nomination. A total of 63 people were matched. When PCS was the top policy, the total PCS cost of this set of assignments was $86,098, with 38 out of 63 people receiving their location preference. When LOCPREF was treated as the top policy, the number of preference matches went up to 50 out of 63 people. However, total PCS cost also increased to $110,527. In other words, 12 additional people received their location preference at an additional cost of $24,429. This translates into more than 2,000 PCS dollars for each additional QM being assigned to a preferred location. Similar figures are reported for the other five ratings as well. Note the contrast between QM and PN, where the tradeoff is smallest.

When analyzing the figures in Table 6, it must be emphasized that these results are specific to the data sets used. The figures should not be interpreted as Navy-wide estimates of the policy tradeoffs involved.

Table 6

Policy Tradeoff: PCS Cost Versus Location Preference (LOCPREF)

Rating	Number of Assignments	Top Priority Policy	No. of People Receiving Their Location Preference	Total PCS Cost	Policy Tradeoff[a]
QM	63	LOCPREF	50	$110,527	
		PCS	38	86,098	
		Diff.	12	24,429	$2,036
SM	46	LOCPREF	32	$104,158	
		PCS	19	83,660	
		Diff.	13	20,498	$1,577
BM	168	LOCPREF	132	$236,360	
		PCS	106	185,849	
		Diff.	26	50,511	$1,943
SH	146	LOCPREF	92	$383,412	
		PCS	68	333,892	
		Diff.	24	49,520	$2,063
PN	68	LOCPREF	38	$130,952	
		PCS	25	117,881	
		Diff.	13	13,071	$1,005
MA	34	LOCPREF	21	$ 75,788	
		PCS	17	64,330	
		Diff.	4	11,458	$2,864

[a]Defined as the incremental cost of satisfying the location preference of one more individual.

We have examined only two assignment policies. One might be interested in including other policies in the analysis. Another policy is requisition priority (REQPRI). It is Navy policy to fill jobs in order of job priority number. This means that the best set of job matches to fulfill this policy has the smallest average priority number. Since policy tradeoffs can be analyzed in a pairwise fashion, we examine the tradeoffs between REQPRI and PCS and between REQPRI and LOCPREF in Tables 7 and 8, respectively.

Table 7

Policy Tradeoff: PCS Cost Versus Requisition Priority (REQPRI)

Rating	Number of Assignments	Top Priority Policy	Average REQPRI Number	Total PCS Cost	Policy Tradeoff[a]
QM	63	REQPRI	14.8	$113,378	
		PCS	17.7	86,116	
		Diff.	-2.9	27,262	$9,401
SM	46	REQPRI	13.4	$ 88,342	
		PCS	15.0	82,668	
		Diff.	-1.6	5,674	$3,546
BM	168	REQPRI	40.5	$258,934	
		PCS	55.1	185,428	
		Diff.	-14.6	73,506	$5,035
SH	146	REQPRI	34.3	$393,066	
		PCS	41.8	333,787	
		Diff.	-7.5	59,279	$7,904
PN	68	REQPRI	22.9	$137,218	
		PCS	28.7	116,707	
		Diff.	-5.8	20,511	$3,536
MA	34	REQPRI	15.4	$ 74,610	
		PCS	17.5	64,330	
		Diff.	-2.1	10,280	$4,895

[a]Defined as the amount by which PCS cost increases when the average requisition priority number improves by one unit.

In Table 7 we see that in order to improve the satisfaction of REQPRI, the Navy must spend more PCS dollars. For instance, for QM personnel, an additional $27,262 is required for improving the average REQPRI by 2.9, translating into a $9,401 per unit cost. The QMs yielded the highest per unit cost. As in Table 6, the contrast is greatest with PN, which has the lowest per unit cost ($3,536). The average per unit cost for all six ratings was $5,720.

Table 8

Policy Tradeoff: Requisition Priority (REQPRI) Versus Location Preference (LOCPREF)

Rating	Number of Assignments	Top Priority Policy	No. of People Receiving LOCPREF	Average REQPRI Number	Policy Tradeoff[a]
QM	63	LOCPREF	50	16.0	
		REQPRI	47	14.8	
		Diff.	3	1.2	0.4
SM	46	LOCPREF	32	15.2	
		REQPRI	28	13.3	
		Diff.	4	1.9	0.475
BM	168	LOCPREF	132	44.1	
		REQPRI	120	40.3	
		Diff.	12	3.8	0.32
SH	146	LOCPREF	92	37.3	
		REQPRI	80	34.3	
		Diff.	12	3.0	0.25
PN	68	LOCPREF	38	26.4	
		REQPRI	31	22.7	
		Diff.	7	3.7	0.53
MA	34	LOCPREF	21	15.9	
		REQPRI	20	15.3	
		Diff.	1	0.7	0.7

[a]Defined as the deterioration in average requisition priority fulfillment to satisfy one more location preference.

In Table 8, REQPRI benefits at the expense of LOCPREF. For instance, the BM results indicate that in order to satisfy 12 additional LOCPREFs, average REQPRI deteriorates by 3.8 points. A similar pattern is found for the other ratings as well. This concludes our examination of rearranging the policy priority. We now turn to changing eligibility requirements.

Changing Eligibility Requirements

As a matter of policy, paygrade substitution is generally not allowed when assigning personnel to jobs. However, this restriction reduces the number of jobs for which each person is eligible. For example, suppose a senior chief in New Orleans, LA, is available for assignment and wants to remain in the same area. Suppose the nearest senior chief billet for which he is eligible is in Norfolk, VA. With no paygrade substitution allowed, the senior chief would be sent to Norfolk. However, suppose there is a master chief billet in New Orleans. If paygrade substitution were allowed, the senior chief could fill the master chief billet, the PCS cost would be greatly reduced, and his location preference would be satisfied. In other words, introducing more flexibility in terms of paygrade substitution may increase the fulfillment of certain assignment policies.

For illustrative purposes, each of the six ratings were run through EPANS under two different eligibility scenarios.[4] In the first scenario, there is no paygrade substitution. In the second scenario, paygrade substitution is allowed as shown in Figure 2. For this example, we chose three assignment policies for EPANS to consider. These policies, in order of priority, are: (a) moving cost (PCS), (b) location preference (LOCPREF), and (c) requisition priority (REQPRI). The results are reported in Table 9.

Job Paygrade	Personnel Paygrade 1-3	4	5	6	7	8	9
1-3	Y	Y					
4	Y	Y	Y				
5		Y	Y	Y			
6			Y	Y	Y		
7				Y	Y	Y	
8					Y	Y	Y
9						Y	Y

Figure 2. Paygrade substitution scenario (Y indicates paygrade substitution, PGSUB). Results of this policy change are shown in Table 9.

[4] In addition to affecting policy outcomes, modifying eligibility rules also changes the number of assignments made. This invalidates any comparison between different eligibility scenarios. To avoid this problem, the more restrictive eligibility scenario was run first. Only the assigned people from this run were used in the less restrictive case. In this way, both scenarios yield the same number of assignments, thus making a valid comparison of policies such as total PCS cost.

The figures in Table 9 show that the top priority policy (PCS) improves as a result of introducing paygrade substitution. PCS cost decreased for every rating when paygrade substitution was allowed. The remaining policies also improve as a result of this change in eligibility, with one exception: The number of preferences satisfied for the MA rating decreased by 1 after the change. It should be noted here that the top priority policy always improves when eligibility is relaxed, while lower level policies may improve or not. With the data used for Table 9, all but one of the lower level policies improved as a result of introducing paygrade substitution.

Table 9

Policy Satisfaction Impact of Changing Eligibility Rules: Introducing Paygrade Substitution (PGSUB)

Rating	Number of Assignments	Policy	Eligibility Restrictions: No PGSUB	Eligibility Restrictions: With PGSUB[a]
QM	63	1. PCS	$ 85,896	$ 70,010
		2. LOCPREF	38	39
		3. REQPRI	17.5	16.3
		Substitutions:	0	37
SM	46	1. PCS	$ 82,638	$ 72,519
		2. LOCPREF	19	21
		3. REQPRI	14.9	13.7
		Substitutions:	0	29
BM	168	1. PCS	$185,839	$151,622
		2. LOCPREF	106	112
		3. REQPRI	55.4	49.9
		Substitutions:	0	110
SH	146	1. PCS	$333,638	$300,896
		2. LOCPREF	68	73
		3. REQPRI	42.0	39.7
		Substitutions:	0	105
PN	68	1. PCS	$117,881	$103,715
		2. LOCPREF	25	27
		3. REQPRI	29.4	22.1
		Substitutions:	0	41
MA	34	1. PCS	$ 64,330	$ 58,048
		2. LOCPREF	17	16
		3. REQPRI	17.5	14.1
		Substitutions	0	17

[a]See Figure 2.

Another eligibility restriction that might be modified is the allowable time lag between personnel projected rotation date (PRD) and job take-up month (TUM). Currently, EPANS allows the member to be matched to the job based on detailer specification about billet gap, for example:

1. The member's PRD equals the job's TUM.
2. His PRD is 1 month before the TUM.
3. His PRD is 2 months before the TUM.

The corresponding assignment policy states that Condition 2 is considered the best choice while Conditions 1 and 3 are tied for the second-best choice. One way to loosen this restriction is to allow this time difference to be widened somewhat. For instance, we could add two more conditions to the list:

4. His PRD is 3 months before the TUM.
5. His PRD is 1 month after the TUM.

Given the typical leave between tours, Condition 4 would allow 1.5 to 2 months overlap between the incumbent and his relief, while Condition 5 would leave the billet vacant for about 1 to 2 months. In terms of assignment policy, Conditions 4 and 5 could be treated as the third-best choice, that is, Conditions 4 and 5 are allowed only if Conditions 1, 2, or 3 cannot be met.

Adding these conditions to the list represents a loosening of the eligibility restrictions because it introduces more assignment alternatives. Because of this, we would expect that fulfillment of the top priority policy improves as a result of this modification. The effect on all lower level policies cannot be predicted and is dependent on the particular data set used. To test this hypothesis, EPANS was used to make two sets of assignments for each of the six ratings: one set for Eligibility Scenario 1 and one set for Eligibility Scenario 2. Scenario 1 is defined as allowing only 0 to 2 months difference between TUM and PRD (Conditions 1-3). Scenario 2 is defined as allowing 0 to 3 months difference between TUM and PRD (Conditions 1-4) plus allowing the PRD to be 1 month after the TUM (Condition 5). The assignment policy priorities used for this set of runs are the same as those used in Table 9 (PCS cost, LOCPREF, and REQPRI) but the policy concerning the matching of PRD and TUM is added as the fourth policy. The score reported for this policy is defined as the number of assignments that are within the 0- to 2-month difference between TUM and PRD allowed by Conditions 1-3. The results are reported in Table 10.

As expected, loosening eligibility restrictions allows fulfillment of the top assignment policy to be improved. For every rating, PCS cost diminished as a result of widening the allowable time difference between PRD and TUM. For instance, under Eligibility Scenario 1, it cost $333,912 to assign 146 SH personnel to jobs. Under Scenario 2, the same 146 people were assigned at a cost of $312,872, a savings of $21,040 ($144 per person). In addition, relaxing eligibility allowed the average REQPRI number to improve by 5.5 points. While most assignment policies improved as a result of the change in eligibility, there were some instances in which policy fulfillment deteriorated. In every case, the fourth policy (match to 2-mo. overlap between TUM and PRD) deteriorated after the eligibility change. This is because (a) this policy was directly affected by the eligibility change and (b) this policy has the lowest priority.

Table 10

Policy Impact of Changing Eligibility Rules:
Increasing Allowable Time Lag

Rating	Number of Assignments	Policy	Date Matching Range 0<(TUM - PRD)<2	-1<(TUM - PRD)<3
QM	63	1. PCS	$ 86,083.	$ 82,045.
		2. LOCPREF	38	39
		3. REQPRI	17.4	15.4
		4. People within 0<(TUM-PRD)<2	63	44
SM	46	1. PCS	$ 83,667.	$ 80,535.
		2. LOCPREF	19	19
		3. REQPRI	14.9	12.7
		4. People within 0<(TUM-PRD)<2	46	30
BM	168	1. PCS	$186,015.	$175,228.
		2. LOCPREF	106	113
		3. REQPRI	55.5	45.6
		4. People within 0<(TUM-PRD)<2	168	114
SH	146	1. PCS	$333,912.	$312,872.
		2. LOCPREF	68	70
		3. REQPRI	42.0	36.4
		4. People within 0<(TUM-PRD)<2	146	95
PN	68	1. PCS	$117,887.	$117,366.
		2. LOCPREF	25	29
		3. REQPRI	29.6	27.1
		4. People within 0<(TUM-PRD)<2	68	57
MA	34	1. PCS	$ 64,330.	$ 57,562
		2. LOCPREF	17	20
		3. REQPRI	17.3	16.8
		4. People within 0<(TUM-PRD)<2	34	26

CURRENT STATUS AND DEVELOPMENT PLANS

EPANS has been modified and expanded to handle the assignment of rated personnel. Eleven ratings (QM, SM, BM, SH, PN, MA, AK, DK, MS, SK, and YN) from the A/D/S assignment branch at NMPC were chosen for the development of this version of the model. The resulting model simultaneously considers all people and jobs to nominate optimum assignments in a very short time. As an example, the model is capable of matching 192 people to 835 jobs in about 3 minutes of CPU time on an IBM 4341/12 computer. This capability can free the detailer's time so that more personal attention can be given to the special cases that arise. The model is structured so that eligibility criteria and assignment policy priorities are under the direct control of the decision maker. This is valuable because changes in assignment regulations and policy can be incorporated into EPANS quickly, and alternative ways of executing policies (different policy orders) can be costed out before the actual assignments are made.

REFERENCES

Blanco, T. A., Liang, T. T., Habel, G., & Ritter, F. (1984, May). Automated enlisted personnel allocation process: Development and testing (NPRDC Tech. Rep. 84-41). San Diego: Navy Personnel Research and Development Center. (AD-A141 953)

Bradley, G., Brown, G., & Graves, G. (1977). Design and implementation of large-scale primal transshipment algorithms. Management Science, 24, 1-35.

Liang, T. T. (1984, July). Network formulation of multiple-criterion problems for developing an integrated personnel distribution system in the Navy (NPRDC Tech. Rep. 84-49). San Diego: Navy Personnel Research and Development Center. (AD-A144 204)

Liang, T. T., & Lee, S. (1985). A systems approach to integrate manpower planning and operation. Socio-Economic Planning Sciences, 19(6), 371-377.

Liang, T. T., & Thompson, T. J. (1986, July). Optimizing personnel assignment in the Navy: The Seaman, Fireman, and Airman application (NPRDC Tech. Rep. 86-24). San Diego: Navy Personnel Research and Development Center.

Liang, T. T., & Thompson, T. J. (In press). A large-scale personnel assignment model for the Navy. Decision Sciences.

APPENDIX A

EXAMPLE ASSIGNMENT PROBLEM

EXAMPLE ASSIGNMENT PROBLEM

One Assignment Policy

Assume that minimizing PCS cost is the only assignment policy to be considered. There are five people to assign and seven jobs to choose from. Consider person A. We can calculate A's eligibility for Jobs 1 through 7. Suppose the results are as follows:

Jobs:	1	2	3	4	5	6	7
Person A	X	O	X	X	X	O	O

where an "X" indicates eligibility and an "O" indicates ineligibility. We can further calculate the PCS cost associated with each potential assignment. Suppose these costs look like this:

Jobs:	1	2	3	4	5	6	7
Person A	3600	-	3800	2700	2500	-	-

Since matching Person A to Job 5 represents the least PCS cost alternative, based on the current manual process of sequentially assigning personnel, we assign Person A to Job 5. Now, Job 5 is filled, denoted by a parentheses.

Let us consider the next person. Suppose person B's eligibility for jobs and potential PCS costs look like this:

Jobs:	1	2	3	4	(5)	6	7
Person B	1000	1100	-	2800	1900	2100	2200

The policy of minimizing PCS costs would indicate that we assign Person B to Job 1. Now, Billets 1 and 5 are filled. For Person C, the eligibility and PCS costs look like this:

Jobs:	(1)	2	3	4	(5)	6	7
Person C	1600	1800	1900	-	1000	1500	-

Note that we cannot assign Person C to the least-cost alternative of 1000 PCS dollars because Job 5 has already been filled. Therefore, we assign Person C to Job 6.

A similar situation occurs for Person D, whose eligibility and cost alternatives are as follows:

Jobs:	(1)	2	3	4	(5)	(6)	7
Person D	1100	-	-	1200	800	-	2500

We would assign Person D to Job 4 and Person E to Job 3.

Jobs:	(1)	2	3	(4)	(5)	(6)	7
Person E	-	2400	1600	2300	1100	1200	2500

The sequential assignment solution can be summarized as follows:

PERSON A -----> JOB 5				
PERSON B -----> JOB 1	Total PCS costs	=	$7,800
PERSON C -----> JOB 6	Avg. cost per move	=	$1,560
PERSON D -----> JOB 4	Number of assignments	=	5
PERSON E -----> JOB 3			

This completes the sequential assignment process with a total PCS funds expenditure of $7,800 and all five people assigned. But is this the minimum PCS cost solution? We saw more than once during the process that the minimum cost alternative for a person was not available because of previous assignment decisions.

We can answer this question by considering all possible sets of assignments simultaneously as an optimization problem. When we do this, we assign all five people at a total PCS cost of only $7,100, a savings of 9 percent. The simultaneous optimization solution can be summarized as follows:

PERSON A -----> JOB 4			
PERSON B -----> JOB 2	Total PCS costs	=	$7,100
PERSON C -----> JOB 5	Avg. cost per move	=	$1,420
PERSON D -----> JOB 1	Number of assignments	=	5
PERSON E -----> JOB 6			

One might ask how difficult it would be to manually find the minimum cost solution for such a small example. If every person were eligibile for all seven jobs, there would be 2,520 different ways to assign people to jobs. Fortunately, the fact that certain people are not eligible for certain jobs reduces the total number of combinations quite a bit. For the example just described, there are 456 ways that all five people can be assigned. A listing of all 456 possible combinations is given in Table A-1.

Although adopting tighter eligibility rules drastically reduces the total number of possible solutions, we would still have difficulty identifying all possible combinations of assignments and finding the minimum cost solution for this example. It would be very time-consuming to manually calculate the total PCS expenditure for each of the 456 different assignment combinations.

Two Assignment Policies

Now assume that in addition to minimizing PCS cost, we want to satisy as many location preferences as possible. Let us use the same PCS cost and eligibility matrix from the single-policy example. We can then add to this data information about individual location preferences. Suppose there are only two locations to consider: Pacific (P) and Atlantic (L). For our example, we assume that individual location preferences (LOCPREF) and job locations are defined as they are reported in Table A-2. For instance,

Table A-1

Listing of All Assignment Combinations[a] for Example Assignment Problem

Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE
1.	12345	41.	14653	81.	16375	121.	31572	161.	34172	201.	35672
2.	12346	42.	14657	82.	16542	122.	31574	162.	34175	202.	35674
3.	12347	43.	14672	83.	16543	123.	31576	163.	34176	203.	36142
4.	12354	44.	14673	84.	16547	124.	31642	164.	34215	204.	36145
5.	12356	45.	14675	85.	16572	125.	31645	165.	34216	205.	36147
6.	12357	46.	15243	86.	16573	126.	31647	166.	34217	206.	36152
7.	12374	47.	15246	87.	16574	127.	31652	167.	34256	207.	36154
8.	12375	48.	15247	88.	17243	128.	31654	168.	34257	208.	36157
9.	12376	49.	15273	89.	17245	129.	31657	169.	34275	209.	36172
10.	12543	50.	15274	90.	17246	130.	31672	170.	34276	210.	36174
11.	12546	51.	15276	91.	17253	131.	31674	171.	34512	211.	36175
12.	12547	52.	15342	92.	17254	132.	31675	172.	34516	212.	36214
13.	12573	53.	15346	93.	17256	133.	32145	173.	34517	213.	36215
14.	12574	54.	15347	94.	17342	134.	32146	174.	34572	214.	36217
15.	12576	55.	15372	95.	17345	135.	32147	175.	34576	215.	36245
16.	12643	56.	15374	96.	17346	136.	32154	176.	34612	216.	36247
17.	12645	57.	15376	97.	17352	137.	32156	177.	34615	217.	36254
18.	12647	58.	15642	98.	17354	138.	32157	178.	34617	218.	36257
19.	12653	59.	15643	99.	17356	139.	32174	179.	34652	219.	36274
20.	12654	60.	15647	100.	17542	140.	32175	180.	34657	220.	36275
21.	12657	61.	15672	101.	17543	141.	32176	181.	34672	221.	36512
22.	12673	62.	15673	102.	17546	142.	32514	182.	34675	222.	36514
23.	12674	63.	15674	103.	17642	143.	32516	183.	35142	223.	36517
24.	12675	64.	16243	104.	17643	144.	32517	184.	35146	224.	36542
25.	14253	65.	16245	105.	17645	145.	32546	185.	35147	225.	36547
26.	14256	66.	16247	106.	17652	146.	32547	186.	35172	226.	36572
27.	14257	67.	16253	107.	17653	147.	32574	187.	35174	227.	36574
28.	14273	68.	16254	108.	17654	148.	32576	188.	35176	228.	37142
29.	14275	69.	16257	109.	31245	149.	32614	189.	35214	229.	37145
30.	14276	70.	16273	110.	31246	150.	32615	190.	35216	230.	37146
31.	14352	71.	16274	111.	31247	151.	32617	191.	35217	231.	37152
32.	14356	72.	16275	112.	31254	152.	32645	192.	35246	232.	37154
33.	14357	73.	16342	113.	31256	153.	32647	193.	35247	233.	37156
34.	14372	74.	16345	114.	31257	154.	32654	194.	35274	234.	37214
35.	14375	75.	16347	115.	31274	155.	32657	195.	35276	235.	37215
36.	14376	76.	16352	116.	31275	156.	32674	196.	35612	236.	32716
37.	14572	77.	16354	117.	31276	157.	32675	197.	35614	237.	37245
38.	14573	78.	16357	118.	31542	158.	34152	198.	35617	238.	37246
39.	14576	79.	16372	119.	31546	159.	34156	199.	35642	239.	37254
40.	14652	80.	16374	120.	31547	160.	34157	200.	35647	240.	37256

[a]The five-digit number represents the jobs to which Persons A, B, C, D, and E are assigned, respectively. For instance, assignment combination No. 10 has a value of 12543. This means that Person A gets assigned to Job 1, Person B to Job 2, C to 5, D to 4, and E to 3.

Table A-1 (Continued)

Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE	Comb. No.	ABCDE
241.	37512	281.	42316	321.	46173	361.	47652	401.	54172	441.	57146
242.	37514	282.	42317	322.	46175	362.	47653	402.	54173	442.	57213
243.	37516	283.	42356	323.	46213	363.	51243	403.	54176	443.	57214
244.	37542	284.	42357	324.	46215	364.	51246	404.	54213	444.	57216
245.	37546	285.	42375	325.	46217	365.	51247	405.	54216	445.	57243
246.	37612	286.	42376	326.	46253	366.	51273	406.	54217	446.	57246
247.	37614	287.	42513	327.	46257	367.	51274	407.	54273	447.	57312
248.	37615	288.	42516	328.	46273	368.	51276	408.	54276	448.	57314
249.	37642	289.	42517	329.	46275	369.	51342	409.	54312	449.	57316
250.	37645	290.	42573	330.	46312	370.	51346	410.	54316	450.	57342
251.	37652	291.	42576	331.	46315	371.	51347	411.	54317	451.	57346
252.	37654	292.	42613	332.	46317	372.	51372	412.	54372	452.	57612
253.	41253	293.	42615	333.	46352	373.	51374	413.	54376	453.	57613
254.	41256	294.	42617	334.	46357	374.	51376	414.	54612	454.	57614
255.	41257	295.	42653	335.	46372	375.	51642	415.	54613	455.	57642
256.	41273	296.	42657	336.	46375	376.	51643	416.	54617	456.	57643
257.	41275	297.	42673	337.	46512	377.	51647	417.	54672		
258.	41276	298.	42675	338.	46513	378.	51672	418.	54673		
259.	41352	299.	45172	339.	46517	379.	51673	419.	56142		
260.	41356	300.	45173	340.	46572	380.	51674	420.	56143		
261.	41357	301.	45176	341.	46573	381.	52143	421.	56147		
262.	41372	302.	45213	342.	47152	382.	52146	422.	56172		
263.	41375	303.	45216	343.	47153	383.	52147	423.	56173		
264.	41376	304.	45217	344.	47156	384.	52173	424.	56174		
265.	41572	305.	45273	345.	47213	385.	52174	425.	56213		
266.	41573	306.	45276	346.	47215	386.	52176	426.	56214		
267.	41576	307.	45312	347.	47216	387.	52314	427.	56217		
268.	41652	308.	45316	348.	47253	388.	52316	428.	56243		
269.	41653	309.	45317	349.	47256	389.	52317	429.	56247		
270.	41657	310.	45372	350.	47312	390.	52346	430.	56273		
271.	41672	311.	45376	351.	47315	391.	52347	431.	56274		
272.	41673	312.	45612	352.	47316	392.	52374	432.	56312		
273.	41675	313.	45613	353.	47352	393.	52376	433.	56314		
274.	42153	314.	45617	354.	47356	394.	52613	434.	56317		
275.	42156	315.	45672	355.	47512	395.	52614	435.	56342		
276.	42157	316.	45673	356.	47513	396.	52617	436.	56347		
277.	42173	317.	46152	357.	47516	397.	52643	437.	56372		
278.	42175	318.	46153	358.	47612	398.	52647	438.	56374		
279.	42176	319.	46157	359.	47613	399.	51673	439.	57142		
280.	42315	320.	46172	360.	47615	400.	52674	440.	57143		

Table A-2

Location Preferences and Job Locations

Person	Location Preference	Job	Location[a]
A	P	1	P
B	L	2	P
C	L	3	P
D	P	4	L
E	L	5	L
		6	L
		7	L

[a]P = Pacific, L = Atlantic.

Person A prefers to be stationed in the Pacific region while Person B prefers the Atlantic region. We can then set up the following Eligibility/PCS Cost/Location matrix:

	(P) 1	(P) 2	(P) 3	(L) 4	(L) 5	(L) 6	(L) 7
Job: / Person:							
(P) A	3600	-	3800	2700	2500	-	-
(L) B	1000	1100	-	2800	1900	2100	2200
(L) C	1600	1800	1900	-	1000	1500	-
(P) D	1100	-	-	1200	600	-	2500
(L) E	-	2400	1600	2300	1100	1200	2500

We need to devise a method of manual assignment for this problem. To do this, we need to determine the priority order of the two policies.

Location as Top Policy

Suppose it is determined that satisfying location preference is more important than minimizing PCS cost. In other words, on a sequential basis, we will pick the least PCS cost move of all assignment alternatives that satisfy location preferences. For Person A, we can only consider Jobs 1 through 3. Of the two jobs for which A is eligible, Job 1 represents the smaller PCS cost. Therefore, we assign Person A to Job 1. For Person B, we can only consider Jobs 4 through 7. Of these, Job 5 represents the least-cost alternative. Therefore, we assign Person B to Job 5. For Person C, we see that the least-cost choice has already been taken. Therefore, we assign Person C to the next best alternative, which is Job 6. When we get to Person D, we see that the only job for which he is eligible has been taken. Therefore, Person D goes unassigned. For Person E, the logical choice is Job 4.

The results of sequential assignment with two policies can be summarized as follows:

PERSON A	----->	JOB 1	Total PCS costs	= $9,300
PERSON B	----->	JOB 5	Avg. cost per move	= $2,325
PERSON C	----->	JOB 6	LOCPREF met	= 4
PERSON D	----->	JOB 0	Number of assignments	= 4
PERSON E	----->	JOB 4		

A few points can be made. All people that were assigned were given their location preference. However, the sequential process resulted in one person not getting assigned. Also notice that adding a second policy results in higher average PCS cost per move. When PCS cost minimization was the only policy, manual assignment yielded an average PCS cost per move of $1,560, as was described in the previous section. When both location preference and PCS cost were considered, the average cost per move was $2,325.

We now consider the optimal solution to this problem. When the two-policy assignment problem is formulated as a capacitated network problem, the following simultaneous optimization solution is given:

PERSON A	----->	JOB 3	Total PCS costs	= $9,300
PERSON B	----->	JOB 7	Avg. cost per move	= $1,860
PERSON C	----->	JOB 5	LOCPREF met	= 5
PERSON D	----->	JOB 1	Number of assignments	= 5
PERSON E	----->	JOB 6		

Note here that all five people get assigned, with all five receiving their location preference. Also, average PCS cost per move is now $1,860, compared with $2,325 for the manual solution.

PCS Cost as Top Policy

Now assume that minimizing PCS cost is more important than satisfying location preference. That is, if two potential assignments were tied for the least-cost alternative, a choice between the two could be made if only one of them satisfied location preference. Under this policy scenario, the manual assignment procedure that we have devised would result in the following set of assignments:

PERSON A	----->	JOB 5	Total PCS costs	= $7,800
PERSON B	----->	JOB 1	Avg. cost per move	= $1,560
PERSON C	----->	JOB 6	LOCPREF met	= 1
PERSON D	----->	JOB 4	Number of assignments	= 5
PERSON E	----->	JOB 3		

If this problem were solved as a capacitated network problem, the optimal solution would be as follows:

PERSON A	----->	JOB 4	Total PCS costs	= $7,100
PERSON B	----->	JOB 2	Avg. cost per move	= $1,420
PERSON C	----->	JOB 5	LOCPREF met	= 3
PERSON D	----->	JOB 1	Number of assignments	= 5
PERSON E	----->	JOB 6		

Notice that both PCS expenditure and satisfaction of location preference improved with the simultaneous optimization approach. The results of all three examples are summarized in Table A-3.

Table A-3

Summary of Results for Example Assignment Problem

Policy Ordering	Manual Assignment	Network Optimization
1. PCS only		
PCS cost per move	$1,560	$1,420
LOCPREF met	-	-
Number of assignments	5	5
2. 1 = LOCPREF; 2 = PCS		
PCS cost per move	2,325	1,860
LOCPREF met	4	5
Number of assignments	4	5
3. 1 = PCS; 2 = LOCPREF		
PCS cost per move	1,560	1,420
Location preference ment	1	3
Number of assignments	5	5

APPENDIX B

NETWORK FLOW MODEL FOR ASSIGNMENT OF RATED PERSONNEL

NETWORK FLOW MODEL FOR ASSIGNMENT OF RATED PERSONNEL

A network is a collection of nodes and arcs. The direction of flow through the arc is indicated by the arrowhead of the arc. In our model, each arc is assigned two parameters: a capacity, which is the maximum amount of flow that the arc can carry, and a cost for each unit of flow that passes through the arc. The required quantities of flow entering or leaving the network at each node are also specified. Flows entering the network are often called the supply, and flows leaving the network are called the demand. Flow is conserved at each node.

The flows on the arcs are controllable within the limits, or constraints, set by arc capacities, conservation of flow, and external supply and demand. These arc flows are the decision variables of an optimization problem. The problem is to choose the arc flows that minimize the total cost of flow through the network, while still satisfying the above restrictions.

Eligibility, assignment policies, and allocation policies are combined into a single network model as shown in Figure B-1. This type of network model is called a "pure minimum cost flow model" or a "capacitated transshipment model." Flows enter the network at Nodes P1 through Pm and leave the network at Node D. These supply and demand values are equal to the number of personnel available for assignment. The Manning Control Authority (MCA) duty type, Chief of Naval Operations (CNO) priority, and paygrade nodes define the allocation policies. The arcs connecting these nodes are each assigned a capacity and a cost. Multiple arcs between pairs of nodes are used for representing nonlinear cost relationships.

Nodes P1 to Pm correspond to people and Nodes J1 to Jn correspond to jobs. If a person is eligible for a given job, there is an arc connecting the corresponding person and job node. This arc has a capacity of one and a cost based on the assignment policies. This cost is determined by quantifying each assignment policy, calculating the policy values that the potential assignment implies, and then forming a weighted sum of these policy values. The weights are constructed so that assignment policies are optimized in preemptive order. When searching for an optimal solution, improvement in the first policy is more important than improvement in the second policy, which is more important than improvement in the third policy, etc. A lower level policy can only be improved if there is a tie between at least two solutions as measured by the next highest policy in the priority list. Using weights in this manner does not always give strictly preemptive solutions. However, the benefits of computational simplicity outweigh the difficulty of using a strictly preemptive solution algorithm for the model.

The EPANS network can be described mathematically in the following way: Assume that there are M people to match to N jobs, subject to several eligibility criteria and assignment policies. Let K be the number of assignment policies to optimize, with the preemptive ordering of these policies being determined by the detailer. Let I represent

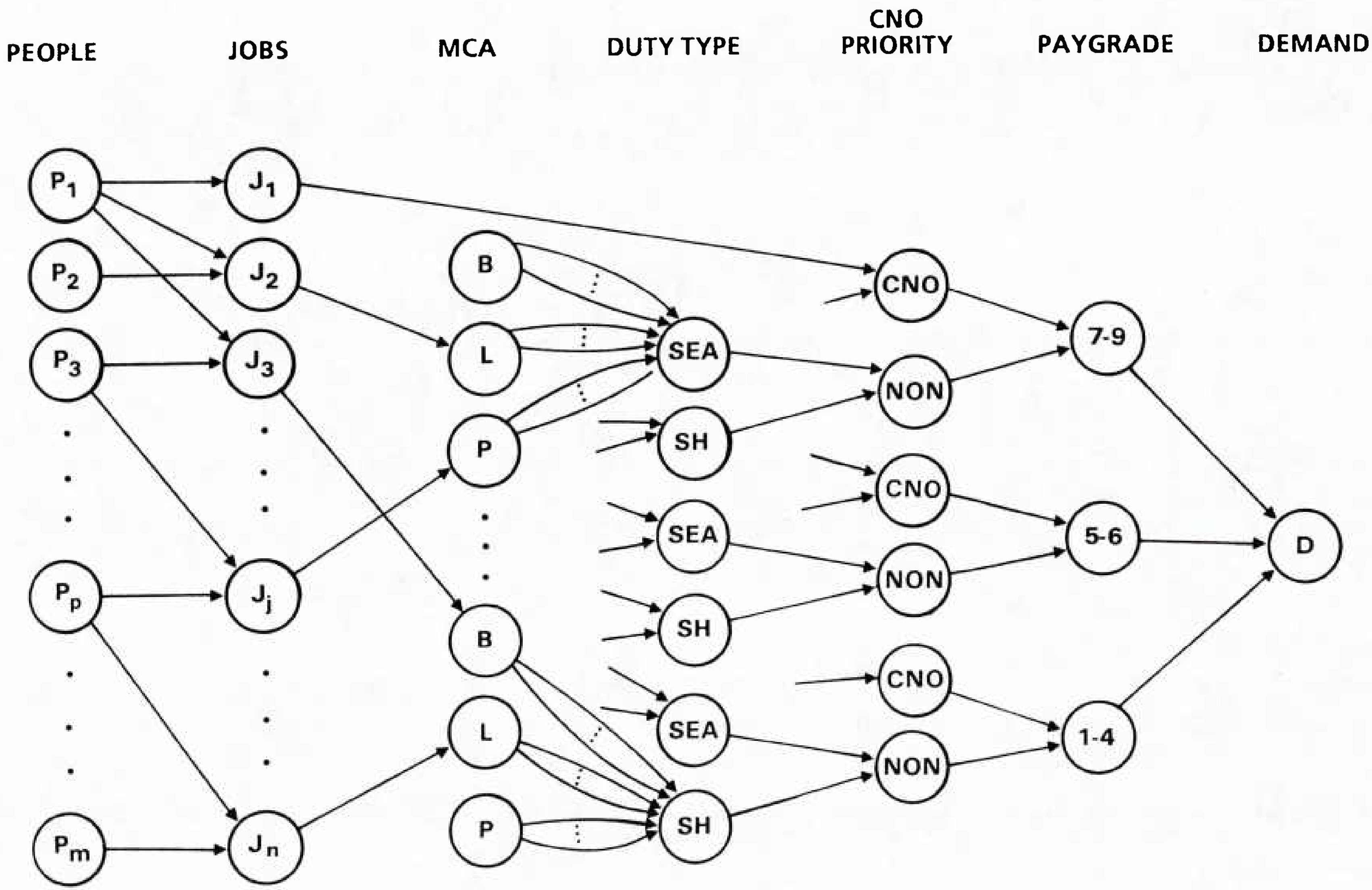

Figure B-1. Network flow model for rated assignment.

the total number of nodes and J represent the total number of arcs. Define an I x J matrix, A, whose elements are defined as follows:

$a_{ij} = +1$ if Arc j is directed away from Node i

$a_{ij} = -1$ if Arc j is directed toward Node i

$a_{ij} = 0$ otherwise

Matrix A is called the node-arc incidence matrix and defines the structure of the network. Furthermore, let

x_j = the flow through Arc j

c_j^k = the cost associated with the kth policy for each unit of flow through Arc j

u_j = the flow capacity for Arc j

r_i = the requirement at Node i

w_k = the relative weight for the kth policy

Given these definitions, the network flow problem can be stated as follows:

$$\text{minimize} \quad \sum_{k=1}^{k} w_k \left(\sum_{j=1}^{J} c_j^k \, x_j \right)$$

$$\text{subject to} \quad \sum_{j=1}^{J} a_{ij} \, x_j = r_i, \qquad \text{for } i = 1, 2, \ldots, I$$

$$\text{and} \quad 0 \leq x_j \leq u_j$$

The solution to this problem is a vector x_j^* (j = 1, 2, ... , J) that identifies the optimal flow through each arc in the network. These flows collectively represent the minimum cost of the maximum number of assignments that can be made.

APPENDIX C

QUANTIFICATION OF ASSIGNMENT POLICIES

QUANTIFICATION OF ASSIGNMENT POLICIES

The assignment policies are incorporated into the network optimization model by converting them into numerical values that fall within a relatively narrow interval. These values are used as coefficients on the arcs that represent flows of personnel through the network. The size of an arc's coefficient is determined by the policy implications of allowing personnel to flow through that arc. For instance, in terms of PCS cost, a move from Norfolk to San Diego would have a larger coefficient (cost) associated with it than a move from Norfolk to Washington, DC.

The fact that policies that normally cover a wide range of values are compressed into a narrow interval enables us to accomplish two objectives. First, smaller coefficients allow more policies to fit in a given amount of computer storage while still maintaining policies in preemptive order. Second, scaling policy values in this way introduces some tradeoffs that allow the implementation of lower level policies to be improved. This second advantage arises because the grouping of policy scores treats similar values as though they were identical, sometimes allowing large improvements in lower level policies at the expense of only slight degradations in higher level policies. For example, an assignment that costs 950 PCS dollars but is not the member's location preference should probably not be considered a better choice than a 1,000-dollar move to his preferred location. For only 50 extra dollars, we could send the member where he wants to go. An example illustrating the effects of scaling on policy tradeoffs is given in Appendix D.

The coefficients representing the assignment policies are detemined in the following manner:

1. Individual Location Preference:

2	if assigned to first preference
3	if assigned to same geographical area as first preference
4	if assigned to second preference
5	if assigned to same geographical area as second preference
6	if assigned to third preference
7	if assigned to same geographical area as third preference
10	if no preference specified
20	if no preference is met

2. Moving Distance:

Moving distance is used as a measure for PCS cost. The great circle distance between locations is calculated using latitude and longitude values. This distance is transformed via the integer part of $r/7.5$, where r is the square root of distance. This results in 15 groups scored as follows.

0	if	0	to	56	miles
1	if	57	to	224	miles
2	if	225	to	506	miles
3	if	507	to	899	miles
4	if	900	to	1406	miles
5	if	1407	to	2024	miles
6	if	2025	to	2756	miles
7	if	2757	to	3599	miles
8	if	3600	to	4556	miles
9	if	4557	to	5624	miles

10	if	5625	to	6806	miles
11	if	6807	to	8099	miles
12	if	8100	to	9506	miles
13	if	9507	to	11024	miles
14	if over 11024 miles				

3. Requisition Priority:

The eight-digit requisition number is used to define requisition priority. The first four digits are the requisition file date. The next three digits are the requisition priority. The square root of this value is used to quantify the requisition priority policy. The last digit of the requisition number is a special qualifier that is not used.

4. Difference Between Availability Date and Vacancy Date:

The difference between personnel availability date and job vacancy date is defined by

$$|(12y_2 + m_2) - (12y_1 + m_1) - 1|$$

where y_1 is the year and m_1 the month of person availability and y_2 is the year and m_2 the month of job vacancy.

5. CNO Priority:

The CNO priority policy is scored as follows.

1 if CNO Priority 1 or 2
2 if CNO Priority 3
5 otherwise

6. Sea/Shore Policy for Females:

Females who are eligible for sea duty can also be assigned to overseas shore duty. The policy is scored as follows.

1 if sea/shore code is 2, 3, or 4
2 if sea/shore code is 6

7. NEC Matching Policy:

The NEC policy is scored as follows.

1 if the person's NEC matches the job NEC
2 otherwise

8. Paygrade Substitution Policy:

When paygrade substitution is allowed, it is scored as follows.

1 if person's paygrade equals job paygrade
2 if person's paygrade is one up from job requirement
3 if person's paygrade is one down from job requirement

APPENDIX D

THE EFFECTS OF SCALING ON POLICY TRADEOFFS

THE EFFECTS OF SCALING ON POLICY TRADEOFFS

Suppose we are concerned with executing two policies: PCS cost is the most important, followed by satisfaction of location preferences. Assume we are faced with an assignment problem of matching three people to four jobs. Job locations and individual location preferences (LOCPREF) are as follows:

Person	LOCPREF	Job	Location[a]
A	L	1	P
B	P	2	P
C	P	3	L
		4	L

[a]P = Pacific, L = Atlantic.

Let the PCS cost associated with each potential move be as defined in the following matrix:

	Job:	1	2	3	4
Person:					
	A	110	225	160	600
	B	500	330	440	320
	C	250	280	400	550

Given all this information, the optimal solution resulting from network optimization is given by the following diagram:

	Job:	(P) 1	(P) 2	(L) 3	(L) 4		
Person:							
(L) A		(110)	225	160	600	PCS cost	= 710
(P) B		500	330	440	(320)	LOCPREF	= 1
(P) C		250	(280)	400	550		

where the selected assignments are indicated by parentheses around the appropriate PCS cost figures. This solution represents the minimum PCS expenditure for assigning all three people. However, the second policy of satisfying location preference leaves room for improvement, since only one out of three people got a preferred location.

One way to improve satisfaction of location preferences is to simply redefine PCS costs by regrouping them in the following manner:

PCS Cost	New Value
100-199	1
200-299	2
300-399	3
400-499	4
500-599	5
600-699	6

After this conversion, the new PCS cost matrix would look like this:

	Job: 1	2	3	4
Person:				
A	1	2	1	6
B	5	3	4	3
C	2	2	4	5

With this new cost matrix, the optimal solution would be:

Job:	(P) 1	(P) 2	(L) 3	(L) 4		
Person:						
(L) A	1	2	(1)	6	PCS cost =	740
(P) B	5	(3)	4	3	LOCPREF =	3
(P) C	(2)	2	4	5		

where the PCS cost of 740 is the actual PCS cost (before rescaling) of the new set of assignments.

Notice that in the new solution we have improved the number of location preferences satisfied by two. The reason is that after the regrouping of PCS policy values, Jobs 1 and 3 are equivalent for Person A (whereas Job 3 would cost more before rescaling). This allowed us to switch A's assignment from Job 1 (which was not his location preference) to Job 3 (which was his location preference). Hence, compressing PCS policies into a small group of values allowed some tradeoffs in the lower level policy (satisfaction of location preference). The ultimate effect of this procedure was to allow a significant improvement in the lower level policy (a 200% increase in the number of preferences met) at the expense of only a slight degradation in the higher level policy (a 4% increase in PCS cost).

DISTRIBUTION LIST

Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics)
Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology)
Military Assistant for Training and Personnel Technology (OSUDS) (R&AT)
Assistant Secretary of the Navy (Manpower and Reserve Affairs) (OASN) (M&RA)
Deputy Assistant Secretary of the Navy (Manpower)
Chief of Naval Operations (OP-01), (OP-01B2), (OP-01B6), (OP-01B7) (2), (OP-11), (OP-13), (OP-132), (OP-132C), (OP-132H), (OP-132H1), (OP-135), (OP-135D), (OP-16), (OP-29), (OP-39), (OP-59), (OP-987H)
Chief of Naval Education and Training
Director of Navy Laboratories (ONT 0722)
Commander, Naval Military Personnel Command (NMPC-00), (NMPC-4), (NMPC-40), (NMPC-40B), (NMPC-40BB), (NMPC-401), (NMPC-402), (NMPC-403), (NMPC-404), (NMPC-405) (10), (NMPC-405C), (NMPC-405D), (NMPC-406), (NMPC-407), (NMPC-408), (NMPC-45), (NMPC-451), (NMPC-452), (NMPC-46), (NMPC-463), (NMPC-47), (NMPC-470), (NMPC-470F), (NMPC-48)
Commander, Navy Recruiting Command (Code 20)
Commanding Officer, Enlisted Personnel Management Center (Code 00), (Code 10), (Code 20), (Code 30), (Code 40), (Code 50), (Code 70)
Chief of Naval Research (Code 111MA), (Code 125), (Code 11), (Code 1111), (Code 114), (Code 1142), (Code 1142PT), (Code 222)
Commander In Chief, U.S. Atlantic Fleet
Commander In Chief, U.S. Pacific Fleet
Commandant of the Marine Corps (MPI-20)
Commander, Army Research Institute for the Behavioral and Social Sciences, Alexandria (PERI-POT-I), (PERI-SZ)
Commander, U.S. Army Soldier Support Center, Ft. Benjamin Harrison, IN, Human Dimensions Division
Commander, Air Force Human Resources Laboratory, Brooks Air Force Base (AFHRL/MO Manpower and Personnel Division), (TSRL/Technical Library FL 2870)
Commandant, Coast Guard Headquarters
President, Naval War College (Code E-1121)
Superintendent, Naval Postgraduate School
Superintendent, (DH), U.S. Coast Guard Academy
Commanding Officer, U.S. Coast Guard Institute
President, National Defense University (3)
Director of Research, U.S. Naval Academy
Center for Naval Analyses
Dr. Ackles, Canadian Defense Liaison Staff, Washington, DC
Canadian Forces Personnel, Applied Research Unit, Canada
DPSRSC, National Defense Headquarters, Canada
Ministry of Defense, Senior Psychologist, England (Naval)
D. Dennison, Army Personnel Research Establishment, Personnel Psychological Division, England (2)
Science 3 (RAF), Lacon House, England
1 Psychological Research Unit, NBH 3-44, Australia
Directorate of Psychology - AF, Department of Defense (Air for CE), Australia
Navy Psychology, Australia (2)
Defense Psychology Unit, Defense HQ, New Zealand (2)
Defense Technical Information Center (DTIC) (2)

DEPARTMENT OF THE NAVY

NAVY PERSONNEL RESEARCH AND
DEVELOPMENT CENTER
(CODE____)
SAN DIEGO, CA 92152-6800

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

U227399

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DoD-316

U.S.MAIL